A Rapidly Deployed Interactive Online Visualization System to Support Fatality Management During the COVID-19 Pandemic

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Keywords (MeSH Terms)

Computer Graphics
Medical Informatics
Pandemics
Population Surveillance
Public Health

ABSTRACT

Objective: To create an online visualization to support fatality management in North Carolina.

Materials and Methods: A web application aggregates online datasets for COVID infection rates and morgue utilization. The data are visualized through an interactive, online dashboard.

Results: The web application was shared with state and local public health officials across NC. Users could adjust interactive maps and other statistical charts to view live reports of metrics at multiple aggregation levels (e.g. county or region). The application also provides access to detailed tabular data for individual facilities.

Discussion: Stakeholders found this tool helpful for providing situational awareness of capacity, hotspots, and utilization fluctuations. Timely reporting of facility and county data were key, and future work can help streamline the data collection process. There is potential to generalize the technology to other use cases.

Conclusions: This dashboard facilitates fatality management by visualizing county and regional aggregate statistics in North Carolina.

INTRODUCTION

By late-May, deaths due to the novel coronavirus disease (COVID-19) had surpassed 100,000 in the US,[1] though public health experts suspect these counts underestimate the true mortality burden.[2] Surges in fatalities have overwhelmed hospitals and funeral homes in many areas, necessitating the deployment of mobile morgues – an unfortunate reality that has garnered national attention in the lay press.[3] Optimal fatality management during the COVID response is therefore an important public health issue requiring timely and transparent data sharing and coordination between public and private entities.

To support this need in North Carolina, we developed an interactive web-based visualization[4,5] to show the distribution of morgues and their capacity levels in real time. This visualization is primarily displayed within the state's Emergency Operations Center. Key stakeholders include governmental public health agencies at the state level, regional health care coalitions, local funeral homes, morgues, crematories, medical examiners, and hospitals. In addition, 10 major hospital systems span North Carolina, together providing much of the infrastructure for acute and critical care where many COVID deaths occur.

Our team aggregated facility-level morgue data that were continuously reported to the state, which we tabulated at the county- and region- levels and presented through an interactive, web-based application. The purpose of this map is to visualize fatality management data to facilitate real-time surveillance and early identification of critical areas where extra support might be needed.

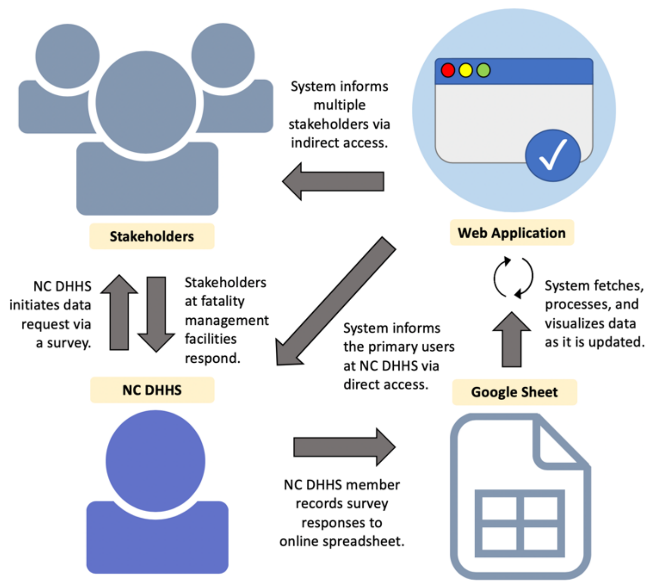
METHODS

The interactive web-based dashboard leverages three sources of data: (a) a public resource containing statistics about confirmed COVID-19 cases, (b) a private access-restricted repository of morgue facility capacity and utilization statistics that was developed for this project and maintained by North Carolina Department of Health and Human Services (NC DHHS), and (c) static metadata describing state counties and regions including geographic boundaries for the rendering of an interactive map. These data sources are updated regularly and made web-accessible as described below.

When a user visits the visualization dashboard via a standard web browser, JavaScript code embedded within the dashboard runs in the browser. This code dynamically retrieves the latest versions of all data sources, processes the data as needed to derive relevant statistics and summaries, and visualizes the results. This approach allows for asynchronous data updates during data gathering, while also ensuring that the dashboard contains the most up-to-date data available at any time.

Interactive capabilities allow users to navigate the datasets to view overviews and details-on-demand for various statistics of interest, with customized views for different user roles. Moreover, a state-dependent bookmarking feature allows users to bookmark specific views within the dashboard, which can be useful for link sharing and collaboration. The overall architecture and data flow are illustrated in

Figure 1. Data flow and system architecture. Stakeholders provide data via survey which are then recorded in a spreadsheet as they are received. The web-based visualization system fetches data from the spreadsheet each time it is loaded by a stakeholder to provide a visualization of the most recent available data for all facilities across the state.



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Data Sources

Data for the number of confirmed COVID-19 cases in North Carolina is obtained from a public database maintained by USAFacts.org.[6] The resource includes county-level statistics and is made available as a URL-accessible comma-separated-value (CSV) data file.

In contrast to the COVID-19 case data, data regarding the capacity and status of mortuary facilities in North Carolina are neither publicly available nor readily visible. To address this, NC DHHS developed a survey instrument to capture key facility information including (a) facility name and address (including county), (b) total capacity, and (c) current utilization, among other details. The online survey was distributed via ReadyOp,[7] a vendor-provided platform to support emergency management and disaster response used by North Carolina and many other states.

The survey is distributed to facilities across the state, including local medical examiners, funeral homes, and morgues, through official communications from the state health department. The survey is also distributed to hospitals via the state's Office of Emergency Management. Recipients are asked to respond a minimum of two times per week (on Mondays and Thursdays), although more frequent responses are encouraged. To allow for the fastest time-to-implementation, the project team opted for a process where survey responses and timestamps are manually copied by a DHHS employee from ReadyOp to an online Google Sheet, which is accessible to the web application in real time via Google's HTTP-based CSV interface.[8]

Metadata resources (county names, map geometry, and region definitions) were gathered during the system design process and stored as statically web-accessible data files.

Web Application

A web application was developed to process and visualize the gathered data. It is implemented in JavaScript (along with HTML/CSS) using Bootstrap[9] and D3js.[10,11] All code runs entirely within a user's web browser (we use the Apache HTTP server), and it requires no server-side execution. Whenever a user visits the visualization dashboard, their browser first retrieves all required HTML, CSS, JavaScript, and image files from the web server. The browser then begins executing the JavaScript code that performs two key steps: (a) data processing and (b) data visualization.

Data Processing. The data processing stage begins with asynchronous GET requests to retrieve all required data resources each time the website is reloaded. JavaScript promises are used to synchronize data processing after the data files have been fully loaded into the browser. A multi-level aggregation is performed on the mortuary facility data to group statistics at the county, regional, and statewide levels. The COVID-19 county-level case counts are aggregated similarly. These aggregate data structures are then linked across each level of detail (county, region, and state) to produce a single unified data structure.

Data Visualization. The visualization dashboard includes two mode selectors (d) and three main display areas (a, b, c) as seen in Figure 2. The mode selectors allow users to select both (1) the metric to be displayed in the visualization and (2) the desired level of aggregation. Metrics include total capacity, occupied capacity, available capacity, occupancy rate, and confirmed case count. The aggregation level can be either county or region. Users can change either selector at any time to trigger an immediate update of the visualization.

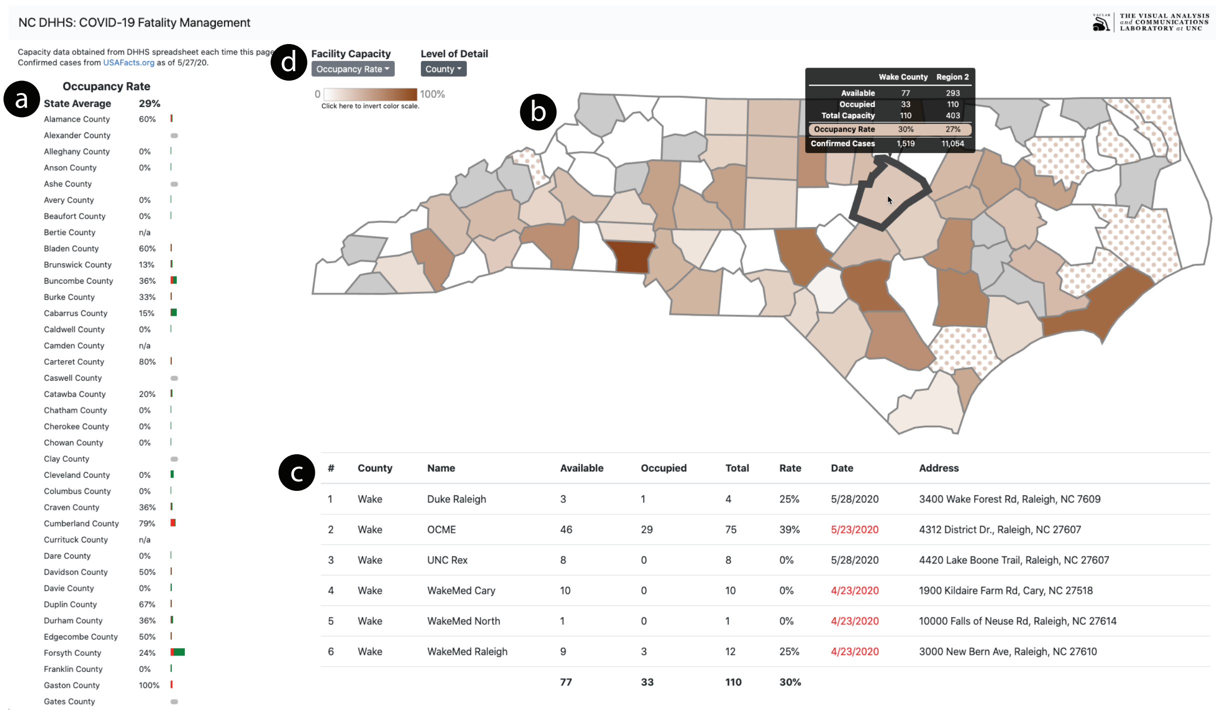

Figure 2. The dashboard includes three sections for displaying data: (a) a list of counties, (b) a choropleth map, and (c) a table of facility data for the selected map area. The view can be configured via (d) the dropdown selectors at the top. This screenshot shows Wake County, NC as the selection.

The first display area (a) contains an alphabetized list of counties showing statewide and county-level statistics for the selected metric. Micro stacked bar charts next to each county provide an overview of occupied and available capacity (which together sum to total capacity), allowing for quick scans for county-level hotspots. Counties with missing data are represented using a distinct short gray bar.

The second display area is a choropleth map of North Carolina. When county-level aggregation is selected, each county is displayed independently. When region-level aggregation is selected, counties are grouped by region and each region has a uniform color (see Figure 3). The map color-codes individual counties or regions based on the metric chosen, where each metric is associated with a distinct color. Missing data is indicated with special color-coding. This is shown in Figure 2 where we distinguish between counties with zero capacity (and therefore an undefined occupancy rate; shown with dotted pattern) vs. counties with missing data (shown in gray). Detailed tooltips showing county- and region-level statistics are displayed on mouseover.

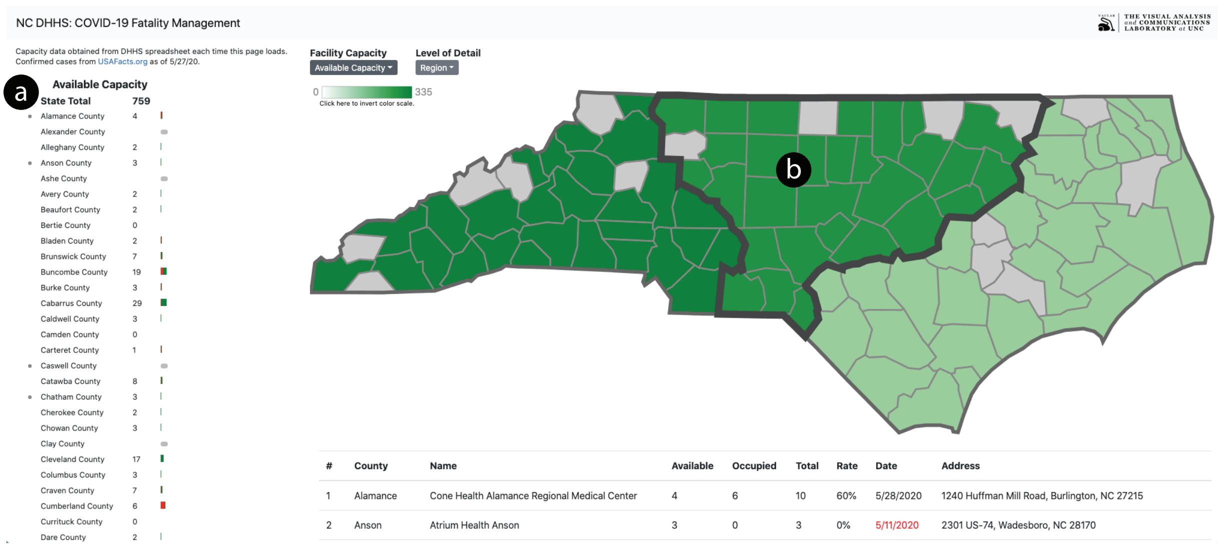

Figure 3. This screenshot shows facility capacity by region. The central region of North Carolina is selected as indicated by (b) the heavy boundary in the map. The county list in the left sidebar has indicators placed to the left of each county in the selected region, and the facility table below the map data for all facilities in the region.

The third display area (c) is a table containing facility-level data. It includes detailed availability, occupancy, and total capacity data, each facility's exact location, as well as a timestamp indicating the most recent update. Facilities with stale data (i.e., data updated over 48 hours ago) are highlighted in red.

Both the alphabetical county left sidebar and the choropleth map allow users to select individual counties. These selections are visually indicated on the map and linked to the table. Each time the selection changes, the table below the map changes to show facilities in the selected county or region.

To support bookmarking for specific views in the visualization, the current view mode is automatically updated in the URL's hashtag fragment identifier whenever a user changes one of the two mode selectors. Users can therefore copy the URL after identifying a view of interest within the dashboard to bookmark for later or to share with collaborators.

Finally, a hidden administrative feature allows data managers access to two additional modes that show average and maximum times since the last survey data update for each facility. This administrative feature can help data managers identify counties where data is most out of date and in need of a manual data collection effort.

RESULTS

Evaluation of the visualization was conducted after initial deployment based on real-world usage patterns and qualitative stakeholder feedback.[12] The chief users of the visualization comprised a small team of public health and emergency management officials who bookmarked the site link and accessed the dashboard daily. Early in the COVID-19 response this occurred primarily through a central monitor at the state's Emergency Operations Center, but access patterns shifted to remote laptops as the Fatality Management team transitioned to work-from-home.

There was variation in the frequency and consistency of survey responses among hospitals and mortuary facilities: some submitted survey data almost daily, whereas others reported weekly or less frequently. After several weeks, reporting patterns reached a "steady state" at which there were regular or semi-regular updates from 85/100 counties. Facility data remained missing for 15/100 counties; geographically, these were evenly distributed across the state.

Qualitative feedback was gathered via an interview with the project's key liaison in the NC DHHS Public Health Preparedness and Response branch and through informal observations of stakeholder usage by one author (CC) who worked directly with users while embedded within DHHS for four weeks (two remotely as the pandemic worsened).[1] Web log data captured by Google Analytics were also reviewed for quantitative insights.

Findings from this limited evaluation are summarized in Table 1, which uses the CDC's evaluation framework for public health surveillance systems[13] to organize feedback according to key system attributes. In general, the system performed favorably across the major dimensions. Through formal feedback and anecdotal reports, users consistently reported high levels of satisfaction with the system, stating they continued to access the application regularly and that it was an essential workflow tool. As of this writing, 405 unique sessions originating in 24 cities have accessed the system with many sessions resulting multiple page views. Traffic was mostly desktop users (91%) though mobile and tablet sessions were also recorded. Access rates were highest in the early phases of the pandemic (avg. 154.5 views per week) before falling to a lower steady-state as the state began a phased re-opening (avg. 11 views per week).

CDC Evaluation Framework Attribute	Observations	Stakeholder Feedback
Usefulness	• Supports day-to-day work at state Emergency Operations Center • Accessed regularly by key stakeholders	*Very helpful!*

[1] Due to time constraints during the pandemic response and other COVID-related priorities, only one stakeholder responded to our invitation to provide structured feedback.

	○ First four weeks (March-April) averaged 154.5 weekly pageviews ○ Decreased to steady state of 11 per week (May-June, as conditions improved and the state began a phased re-opening) • Facilitates state-local communications ○ Web access from 24 cities ○ Broader circulation via emailed reports	*Gave us a sense of individual hot spots as well as looking at the broad picture, such as if there was a certain level of crowding in a given region*
Simplicity	• Intuitive and easy to use	*Very easy to use. Everything was in there*
Flexibility	• Filters to view data at different levels • Integrates fatality data from external source • Users can manipulate color scheme • Users can select multiple data views	*Really liked the rollover feature as I hovered over it. When [we] needed to drill down, [we] could click on a county to see more*
Timeliness	• Data are timestamped • Visual cues indicate data that aren't current	*When we clicked down, we could easily see the last updated date in the table at the bottom*
Data Quality	• Missing data in 15/100 counties • Key stakeholders involved in initial design of data gathering process	*Yeah, there [were] some missing data, but we knew that was due to submitters rather than the system itself*
Sensitivity	• No gaps in data representation on the map • Opportunity for improvement: ability to view historical data to assess trends	*Would be nice if the map let us compare old data*
Acceptability	• High levels of willingness to use the system • Web-based design made the system easy to access ○ 7.4% via phone ○ 1.6% via tablet ○ 91.0% via desktop	
Representativeness	• Adequate data to convey broad picture status • Opportunities for improvement: integrate more epidemiologic data	*Would be nice to include "active counts" of COVID to see areas with active outbreaks*
Stability	• Readily available: no system downtime or offline maintenance • Users found the system to be reliable	*Overall, fairly reliable. Data capture seems to be the biggest issue. [The map] represents well the data that are shared with us.*

Table 1. Feedback gathered during evaluation of the visualization system.

DISCUSSION

This web application integrates multiple data streams into a visualization to support fatality management during the COVID-19 response in North Carolina. The project represents a collaboration between local academic researchers (including trainees), governmental public health practitioners, and emergency management organizations. The 3-person multi-disciplinary team that self-assembled to develop the application was able to identify user requirements, consolidate data sources, develop source code, and launch an interactive prototype in under five days. This rapid start-up was pivotal to the success of the project and required clear communication and teamwork across multiple organizational boundaries.

This work emphasizes the importance of iterative design and development that can respond to quickly evolving user needs. For example, in its initial version, the visualization did not indicate when facility data were last updated, but this information was added later using time stamps and visual emphasis strategies based on stakeholder feedback. Other system capabilities were similarly iterated and improved upon.

Our experience and feedback from stakeholders yielded several ideas for future enhancements to the system. Automating the data export from the survey platform to Google Sheets would improve upon the current system of manual data management. In addition, URL-based access to the visualization dashboard was limited to a handful of stakeholders, while others received static screenshots and did not benefit from the system's interactivity. Future design improvements could account for the value of static information by relying less on mouse-based interaction and displaying more static information. Furthermore, the system has the potential to integrate epidemiological data to provide more context in identifying critical areas for fatality management, as well as a "look back" feature that allows users to compare current county or region status to historical data.

CONCLUSION

Through close collaboration with stakeholders and a rapid iterative development process, a statewide system was developed to gather, process, and visualize morgue facility data at facility, county, and regional levels. This system enables real-time surveillance and has been well-received among public health and emergency management officials involved in COVID-19 disaster response.

ACKNOWLEDGEMENTS

We thank Christine Mullarkey-Campbell from the NC DHHS Public Health Preparedness and Response Branch for her close collaboration and leadership in the work reported in the article.

FUNDING STATEMENT

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

CONTRIBUTOR STATEMENT

SK, CC, and DG all contributed to the writing and editing of the paper. CC was primarily responsible for developing the data gathering aspects of the system. SK and DG were primarily responsible for developing the overall system, including the data flow, web application infrastructure, and user-facing components (including the visualizations).

COMPETING INTERESTS STATEMENT

The authors have no conflict of interests to declare.

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